



8th International Workshop on

Multiple Partonic Interactions at the LHC

San Cristóbal de las Casas, Chiapas. November 28, 2016

Introduction to WG5: high multiplicities and interactions with nuclei Antonio Ortiz (ICN, UNAM) and Boris Blok (Technion, Israel)



Physics of heavy-ion collisions



There is experimental evidence that a strongly interacting Quark-Gluon Plasma (sQGP) is formed in ultra-relativistic heavy-ion collisions

The system is characterized by strong radial and anisotropic flow, as well as opacity to jets (jet quenching)





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Israel Institute

Physics of heavy-ion collisions



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Instituto de Ciencias

However, MB pp collisions were found to be very interesting CHNION Strate Institute of Technology



"The K⁰_S transverse momentum spectrum is overestimated by PYTHIA tune ATLAS-CSC and PHOJET below 0.75 GeV/*c* but is higher by a factor of ~2 in the p_T range [1-3] GeV/*c*.... ...We find that strange baryons are significantly under-predicted in both PYTHIA and PHOJET by a factor of ~ 3"

ALICE, Eur. Phys. J. C71 (2011) 1594

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UNAM



However, MB pp collisions were found to be very interesting control of Technology Institute of Technology



High multiplicity reach, $dN_{ch}/d\eta$ comparable to that measured in semicentral Cu-Cu collisions

JHEP **1101** (2011) 402-407



Instituto de Ciencias However, MB pp collisions were found to be very interesting CHNION **Nucleares UNAM** srael Institute of Technoloav Ar - LIDA. d²N dp_Tdy l_{yl<0.75} (GeV/c)⁻¹ "For increasing N_{ch} , PYTHIA systematically م predicts higher jet rates and harder $p_{\rm T}$ spectra than seen in data ..." CMS, Eur. Phys. J. C73 (2013) 2674 multi-lifes ഗ് soft, $p_{\tau}^{max} < 2 \text{ GeV/c}$ hard, $p_{-}^{max} \ge 2 \text{ GeV/c}$ all 104 ALICE HOJET 10 0.5 p-p, **√**s- 0.2 BUGIA-2011 10 ALICE, Eur. Phys. J. C72 (2012) 2124 107 OWEr)ata / MC 12.1 MC 1 / MC ATLAS, Phys. Rev. D88 (2013) 032004 0.8 30 50 50 20 40 10 20 30 40 10 20 30 40 50 $N_{ch} (p_{\tau} \ge 0.5 \text{ GeV/c})$ $N_{ch} (p_{\tau} \ge 0.5 \text{ GeV/c})$ $N_{ch} (p_{\tau} \ge 0.5 \text{ GeV/c})$ A. Ortiz (ICN) & B. Blok (Technion)

November 28. 2016

And the unexpected "ridge" in pp data



LHC Seminar

Long-Range Near-Side Angular Correlations in Proton-Proton Interactions in CMS.

by Guido Tonelli (Universita' di Pisa, INFN, CERN), Gunther Roland (Massachusetts Institute of Technology (MIT))

21 Sep 2010, 17:00 → 18:00 Europe/Zurich

500-1-001 - Main Auditorium (CERN)

Description The CMS Collaboration Results on two-particle angular correlations for charged particles emitted in proton-proton collisions at center of mass energies of 0.9, 2.36 and 7TeV over a broad range of pseudorapidity (n) and azimuthal angle (φ) are presented using data collected with the CMS detector at the LHC. Short-range correlations in $\Delta\eta$, which are studied in minimum bias events, are characterized using a simple independent cluster parameterization in order to quantify their strength (cluster size) and their extent in η (cluster decay width). Long-range azimuthal correlations are studied more differentially as a function of charged particle multiplicity and particle transverse momentum using a 980nb-1 data set at 7TeV. In high multiplicity events, a pronounced structure emerges in the two-dimensional correlation function for particles in intermediate pT's of 1-3GeV/c, 2.0< |Δη|<4.8 and Δφ≈0. This is the first observation of such a ridge-like feature in two-particle correlation functions in pp or p-pbar collisions

	EVO Universe, password "seminar"; Phone Bridge ID: 2330444 Password: 5142		
Ø	GR-slides 🖄 GT-slides 🖄 🛃 Joint LPCC/EP/PP CERN seminar 🔗 Poster 🖄 Video in CDS	8	
Organised by	M.Mangano, M.Spiropulu, G.Unal		
Webcast	There is a live webcast for this event	atch	

CERN CMS seminar summary:

"Long-range, near side correlation is not seen in low multiplicity events and generators, but resembles effects seen in heavy-ion collisions at high energies"









(d) CMS N \geq 110, 1.0GeV/c<p_<3.0GeV/c



And the unexpected "ridge" in pp data

There are many theoretical interpretations of the ridge in pp and p-Pb collisions

Hydrodynamics

- P. Bozek, Eur. Phys. J. C71 (2011) 1530
- □ K. Werner et al., Phys. Rev. Lett. **106** (2011) 122004
- P. Bozek and W. Broniowski, Phys. Lett. **B718** (2013) 1557

Saturation

- A. Dumitru et al., Phys. Lett. **B697** (2011) 21-25
- M.G. Ryskin, A.D. Martin and V.A. Khoze, J. Phys. G38 (2011) 085006.
- K. Dusling and R. Venugopalan, Phys. Rev. Lett. 108 (2012) 262001

Other mechanisms

- D. d'Enterria et al., Eur. Phys. J. C66 (2010) 173–185
 E. Avsar et al., Phys. Lett. B702 (2011) 394–397
- **.**...





Event multiplicity for fixed system size

Figure taken from: S. Schlichting and P. Tribedy, arXiv:1611.00329



strength

correlation

Azimuthal

And the unexpected "ridge" in pp data

There are many theoretical interpretations of the ridge in pp and p-Pb collisions

Studies of radial flow patterns as a function of the event multiplicity and transverse momentum of the leading jet
 Gyula Bencedi

Event shape dependence of the average
 *p*_T fluctuations in pp collisions
 Irais Bautista

Azimuthal correlation strength



Since high multiplicity events can be also produced by a single high- p_T scattering, experimental tools are needed to classify the events: **event shapes or jet finders**



S. Schlichting and P. Tribedy, arXiv:1611.00329

⊔Hyd

Othe

New developments (using LHC run II data)







ATLAS, Phys. Rev. Lett. 116, 172301 (2016)

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New developments (using LHC run II data)





The collective behavior is usually characterized by cumulants and their Fourier expansions N. Borghini et al., Phys.Rev.C64 (2001) 054901

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New developments (using LHC run II data)





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Identified particle production



ALICE, Phys. Lett. B 760 (2016) 720



More similarities among different colliding systems



Identified particle production









More on identified particle production

- Stefania Bufalino (ALICE)
- □Valentina Mariani (CMS)
- Zhenyu Ye (STAR)
- Lizardo Valencia (ALICE)







More signatures of sQGP in small systems



Strangeness enhancement vs multiplicity in pp and p-Pb collisions at the LHC





More signatures of sQGP in small systems



Strangeness enhancement vs multiplicity in pp and p-Pb collisions at the LHC



